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Ion metal synthesis in viscous organic matter

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Abstract

The viscosity of the irradiated target as new parameter was introduced in ion implantation physics of organic matter. It was experimentally shown that using this parameter one enables to monitor the process of ion synthesis of thin granular impurity films. As an example, the results of high-dose implantation of Co^+ and Ag^+ ions in viscous epoxy experimenting stages of cure (polymerization) process are presented. It was established by TEM that the mean size, size distributions, form and crystalline structure of the synthesized metal particles depend on both ion beam parameters and viscosity of the epoxy target.

The mechanisms of homogeneous nucleation and diffusive growth of metal particles in the low-viscosity epoxy in contrast to heterogeneous nucleation in solid polymers are discussed. The threshold implantation dose that is necessary for the formation of stable metal phase nucleation in a viscous medium was calculated by using the diffusion equation with a continuous Gauss-like source for the implanting impurity. It is shown that the specificity of epoxy polymerization influences the growth and crystalline structure of metal particles at intermediate stages of the epoxy cure process.

The preliminary investigation of magnetic, optical and electrical properties of synthesized films is described as well.

1. Introduction

It is well known [1–4] that thin highly disperse impurity films can be formed in the near-surface volume of the irradiated substrate by using high-dose ion implantation (ion synthesis regime). However, low values of the diffusion coefficient of implanted atoms in solid-state matrices are often the factor limiting nucleation and growth of the new phase. In order to obtain more effective coagulation of impurity atoms in nanoparticles and to increase their crystallinity degree one usually uses either post-implantation annealing of the irradiated matrix [1–3] or ion synthesis on a substrates heated to sufficiently high temperature [4]. It enables one to increase the diffusion mobility of implanted atoms, which is the main mechanism of mass transfer during nucleation and growth of films, and to anneal radiation defects. In this paper, to attain these goals a new principle is proposed and tested. The essence of this principle is that ion synthesis is performed by using high-dose implantation of impurity ions in a viscous-flow organic matrix, in which, as shown by our estimates, the diffusion coefficient of the implanted impurity may exceed those in solid matrix by 7–8 orders of magnitude. After implantation, the matrix transforms into the solid (glassy) state as a result of polymerization. Thus, the variation of the initial value of viscosity of the matrix under irradiation and, consequently, the diffusion coefficient of the impurity enables one to effectively affect nucleation and growth of the new phase. We present below the results of studying some regularities and peculiarities of the ion synthesis of metal particles in a viscous organic medium, and physical properties of synthesized thin films.

2. Experiment

Epoxy compositions, mixture of epoxy resin with polyethylenepolyamine, were used as a model compound due to their long-time relaxation transition (cure process) from the viscous flow state to the solid glassy state. Different stages of the epoxy cure process were characterized by measuring their dynamical viscosity (η) by using a capillary viscometer with accuracy of $\pm 10\%$. Epoxy viscosity varied in the range 20–180 Pa s during the first 250 min of the cure process (Fig. 1).

Samples were prepared by implanting 40-keV Co^+ and Ar^+ and 30-keV Ag^+ ions in the dose range $(0.3–2.5) \times 10^{17}$ cm^{-2} and at current density of 4 $\mu A/cm^2$ into

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